AGENT-BASED MODELING OF TRAFFIC FLOW

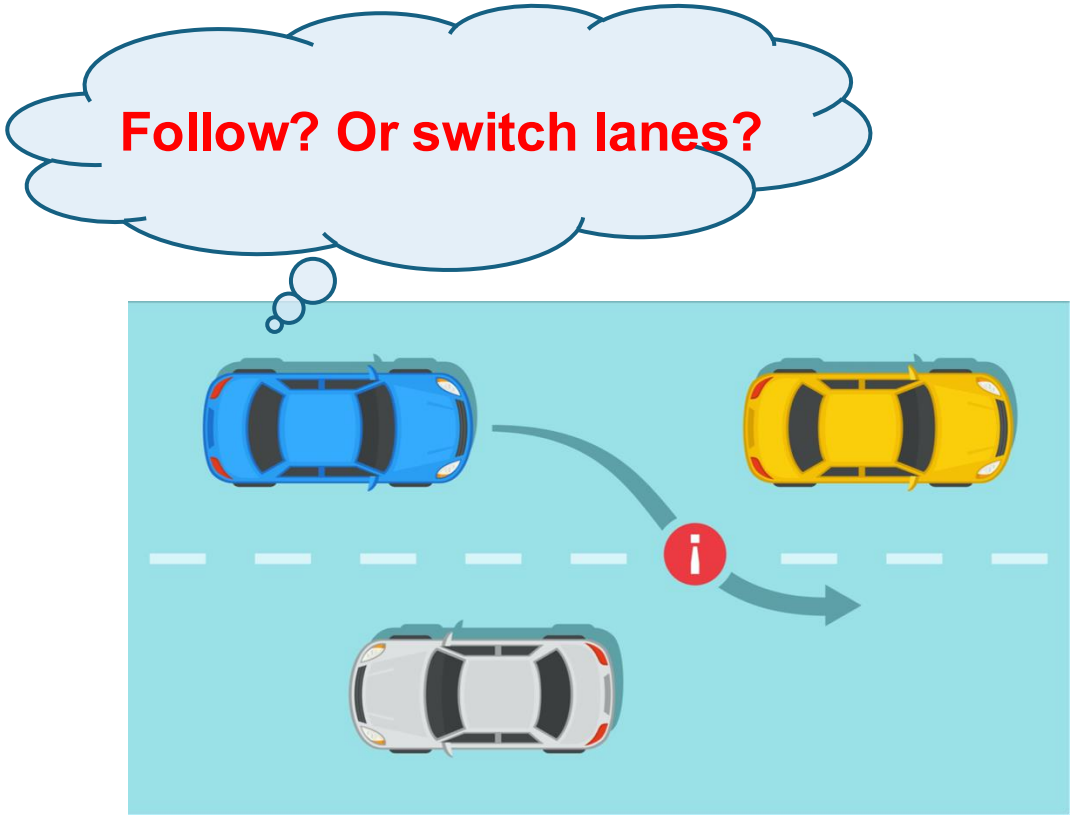
GROUP 1

Li Xiaoyue (A0194485N)
Davendra Shayna Hassan (A0313546H)
Jam Lambert Ubay Catenza (A0299359A)
Prerthan Munireternam (A0200838J)
Shaik Asaaduddin Khwaja (A0329388L)

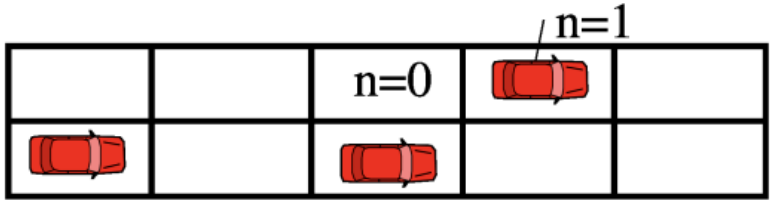
Agent-based traffic models

- Overview of Agent-based Traffic Models
- Description of Models
- Methodology
- Data and Analysis

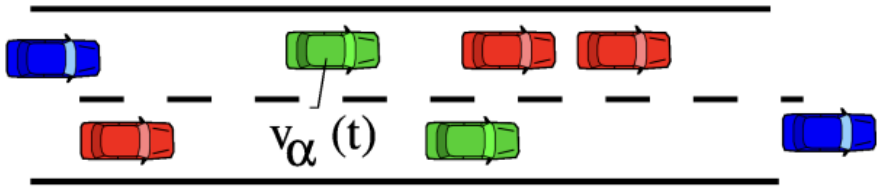
Agent-based traffic models



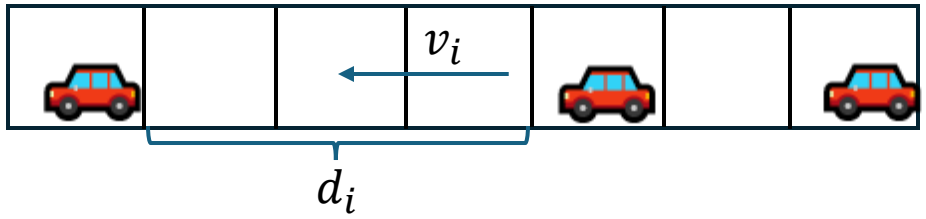
- **Discrete**: Cellular Automata



- **Continuous**: OVM, IDM, MOBIL, etc.



Nagel-Schreckenberg (NaSch) Model



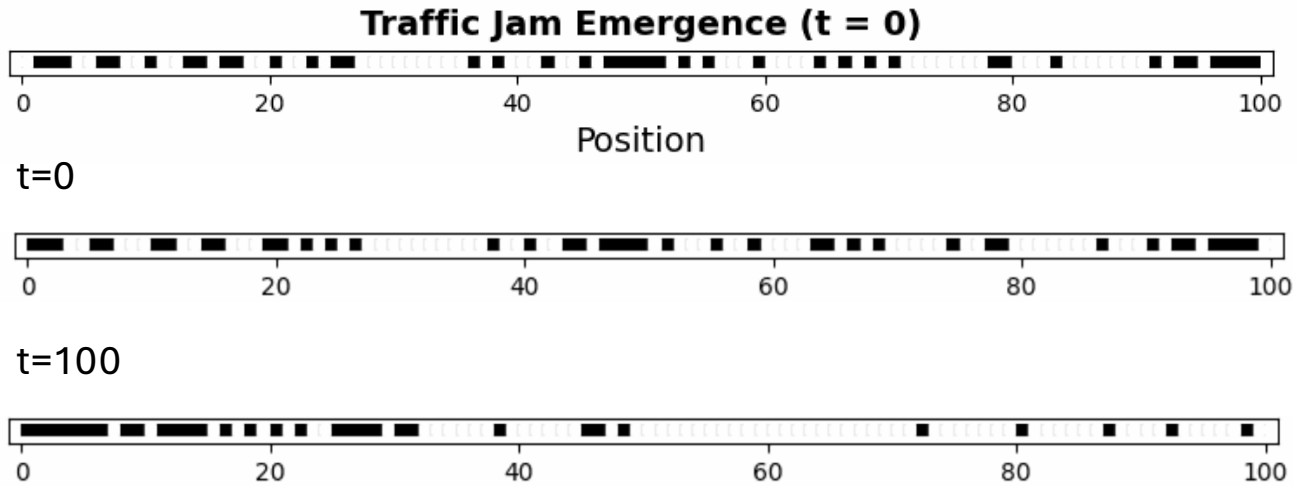
$$v_i(t+1) = \begin{cases} \max\left(\min[v_i(t)+1, v_{\max}, d_i(t)] - 1, 0\right), & \text{with prob. } p, \\ \min[v_i(t)+1, v_{\max}, d_i(t)], & \text{with prob. } 1-p, \end{cases}$$

1 **Acceleration**: $v_i \leftarrow \min(v_i + 1, v_{\max})$

2 **Deceleration**: $v_i \leftarrow \min(v_i, d_i)$

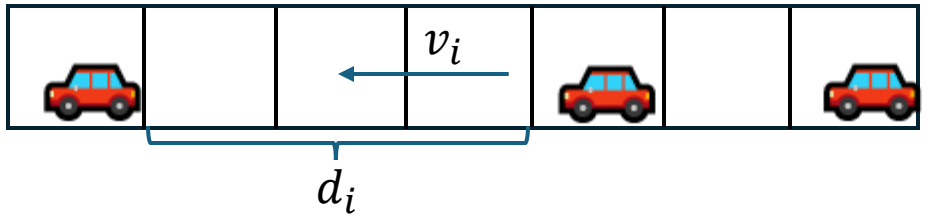
3 **Random slowdown**: with probability p, $v_i \leftarrow \max(v_i - 1, 0)$

4 **Movement**: $x_i(t+1) = x_i(t) + v_i(t)$



$p = 0.35, \rho = 0.4$

Nagel-Schreckenberg (NaSch) Model



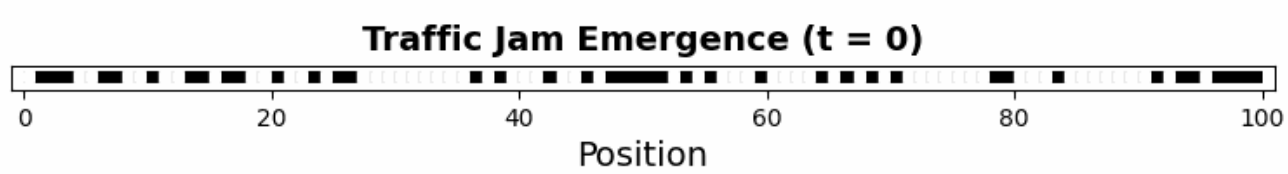
$$v_i(t+1) = \begin{cases} \max\left(\min[v_i(t)+1, v_{\max}, d_i(t)] - 1, 0\right), & \text{with prob. } p, \\ \min[v_i(t)+1, v_{\max}, d_i(t)], & \text{with prob. } 1-p, \end{cases}$$

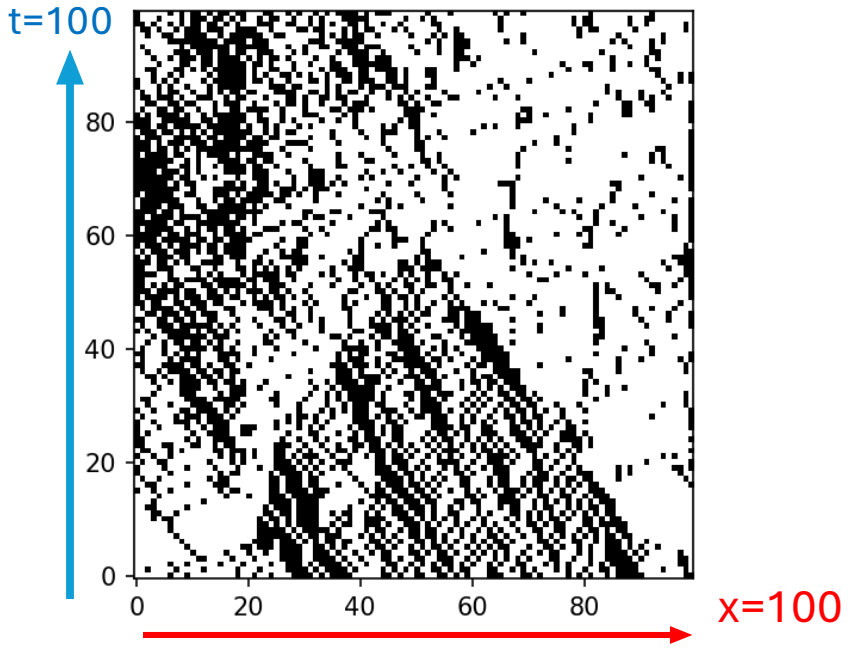
1 **Acceleration**: $v_i \leftarrow \min(v_i + 1, v_{\max})$

2 **Deceleration**: $v_i \leftarrow \min(v_i, d_i)$

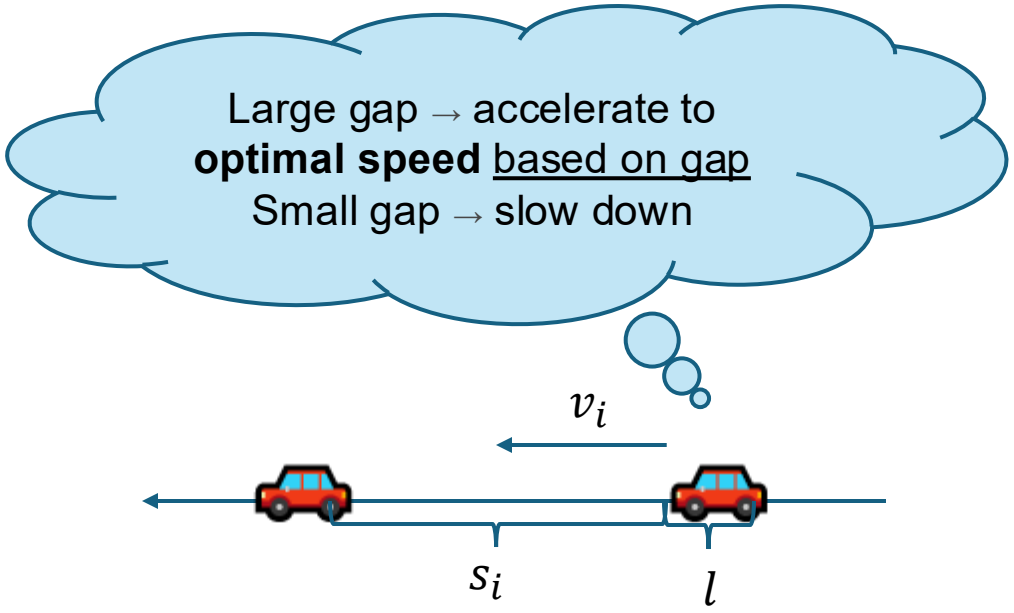
3 **Random slowdown**: with probability p, $v_i \leftarrow \max(v_i - 1, 0)$

4 **Movement**: $x_i(t+1) = x_i(t) + v_i(t)$





Optimal Velocity Model (OVM)



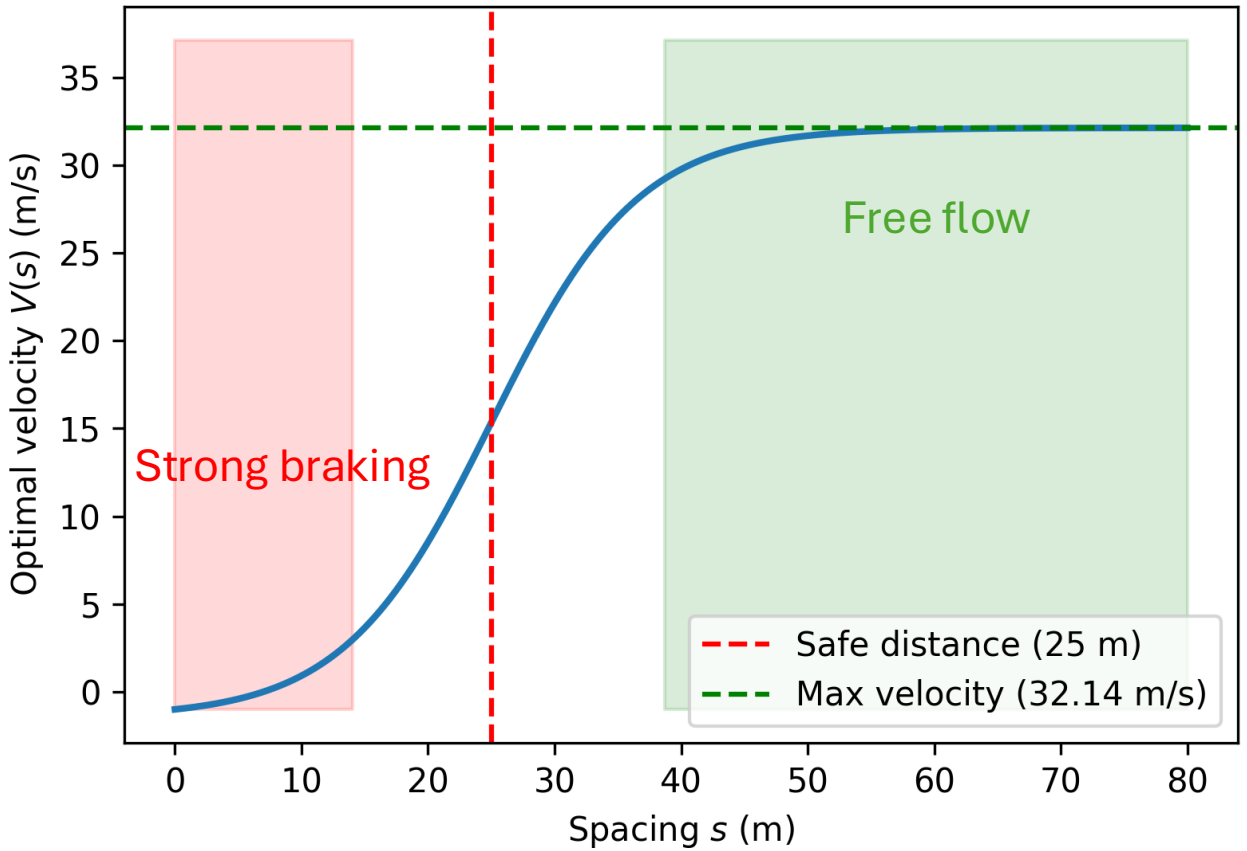
$$\dot{v}_i = \alpha\,[V(s_i) - v_i]$$
$$\dot{x}_i = v_i,\ s_i = x_{i-1} - x_i - l\ ,$$

α : sensitivity (driver reaction speed $\approx 2/s$)

$V(s_i)$: desired or **optimal velocity** function given headway s_i

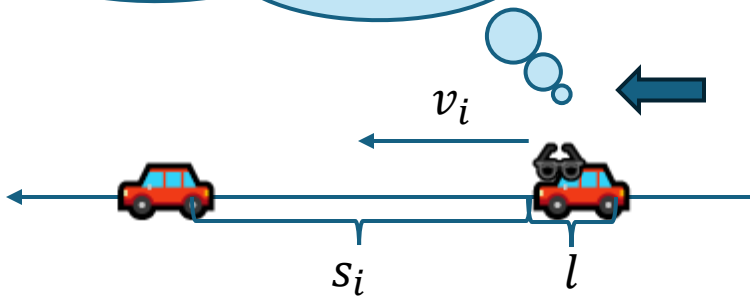
Canonical choice of $V(s)$ (Bando et al., 1998):

$$V(s) = 16.8\,[\tanh 0.0860(s-25) + 0.913]\ .$$



Intelligent Driver Model (IDM)

- Desire to reach **ideal speed**
- Decelerate to maintain a **comfortable gap** depending on how fast I'm closing in



$$\dot{v}_i = a\left[1 - \left(\frac{v_i}{v_0}\right)^{\delta} - \left(\frac{s^*(v_i, \Delta v_i)}{s_i}\right)^2\right],$$

a : maximum acceleration

1 Free-flow term: $a\left[1 - \left(\frac{v_i}{v_0}\right)^{\delta}\right]$

δ : acceleration exponent (≈ 4)
v_0 : desired free-flow speed

2 Interaction term: $-a\left(\frac{s^*(v_i, \Delta v_i)}{s_i}\right)^2$

Δv_i : approaching rate $= v_i - v_{i-1}$
s_i : actual gap to vehicle in front
s^* : desired headway

$$s^*(v_i, \Delta v_i) = s_0 + v_i T + \frac{v_i \Delta v_i}{2\sqrt{ab}}$$

s_0 : standstill gap
T : desired time gap
b: comfortable braking

Methodology

Simulation Framework

Theory-based model logic

Data from OSMnx

Mesa-Geo Library

Model
- Construct Singapore network
- Orchestrates simulation
- Create and manages agents

RoadAgents: Store free-flow speed

VehicleAgents: Move along parent RoadAgent

Critical Point Analysis

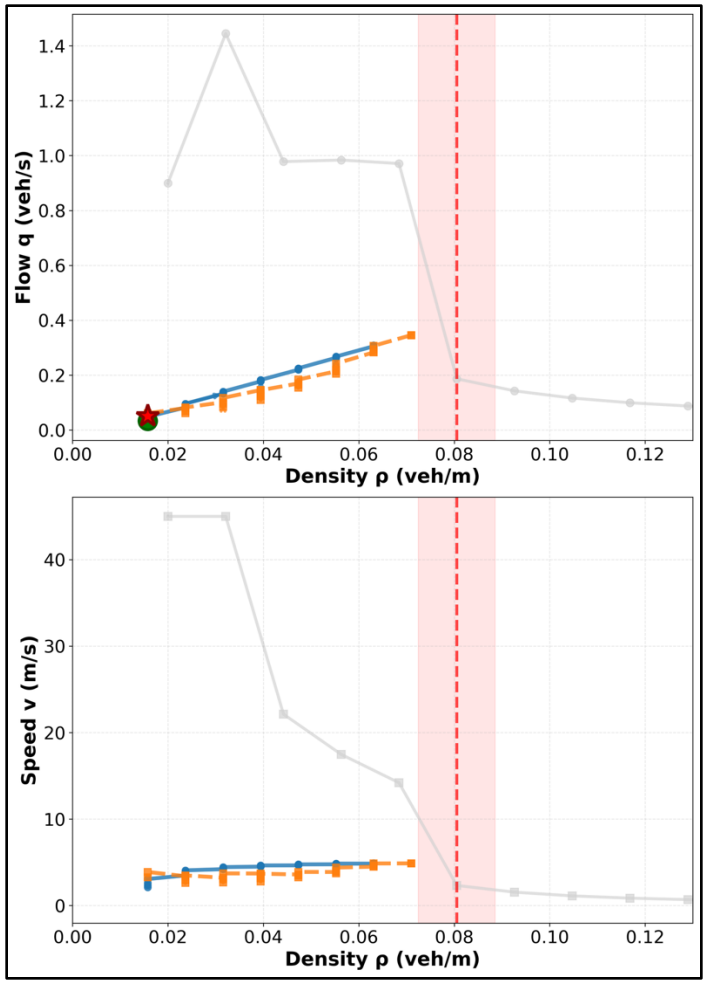
Simulate ring-road over a density range ρ

Plot fundamental diagrams
→ identify ρ*
- Flow q(ρ) vs Density ρ
- Speed v(ρ) vs Density ρ

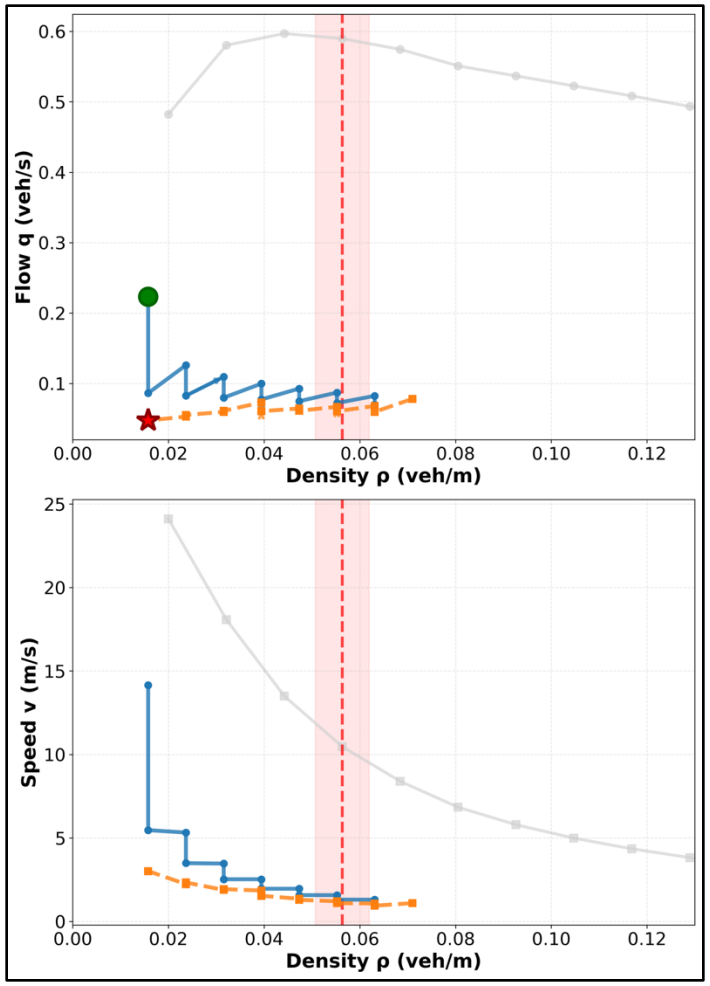
Singapore network
→ Plot q(ρ) and v(ρ) over increasing/decreasing ρ
→ identify hysteresis

Critical Point Analysis

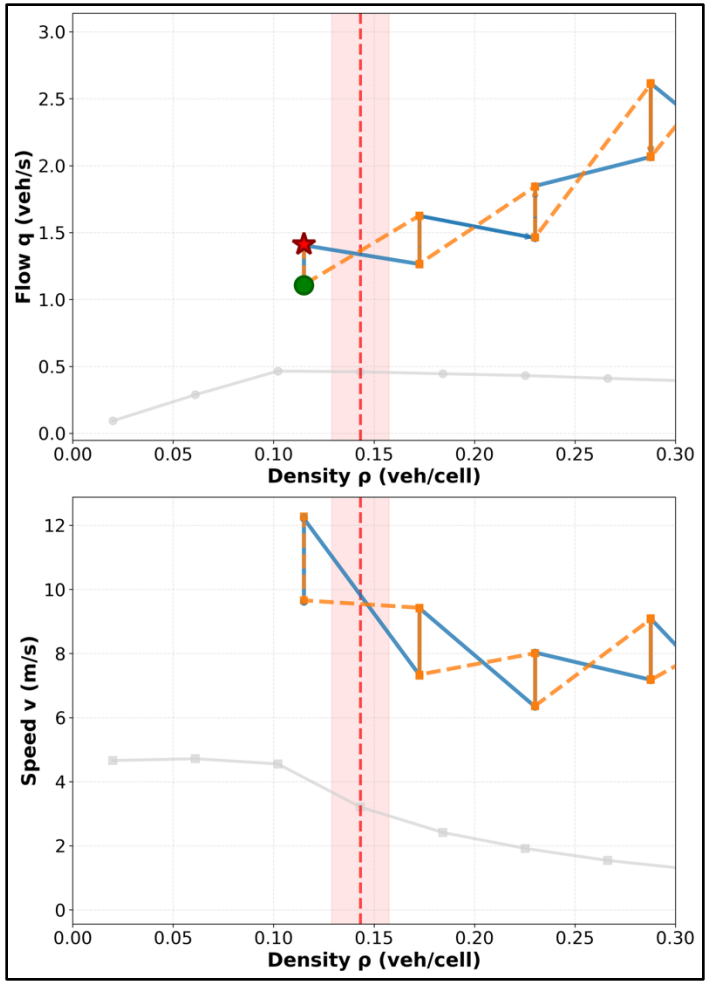
OVM Model



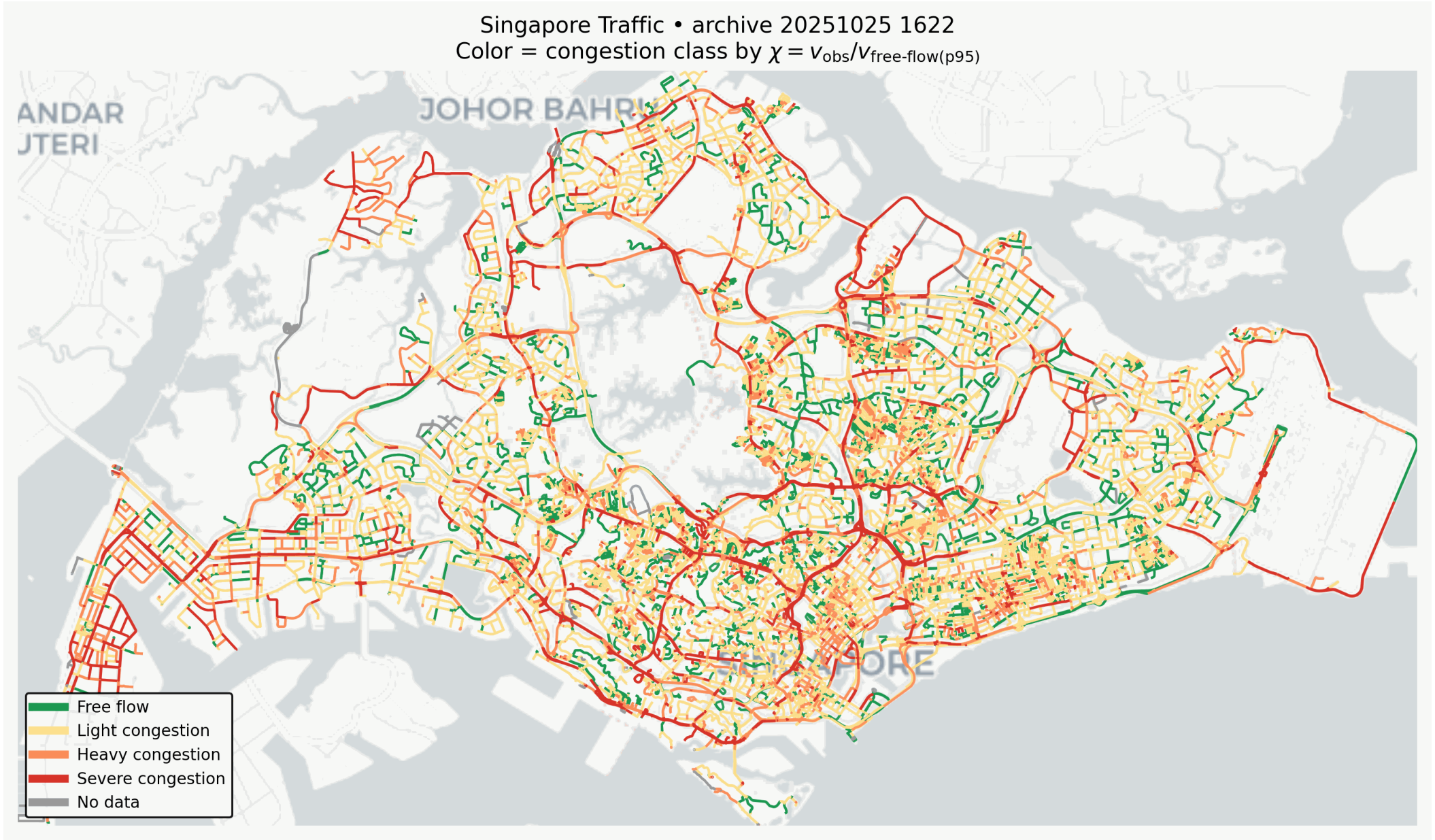
IDM Model



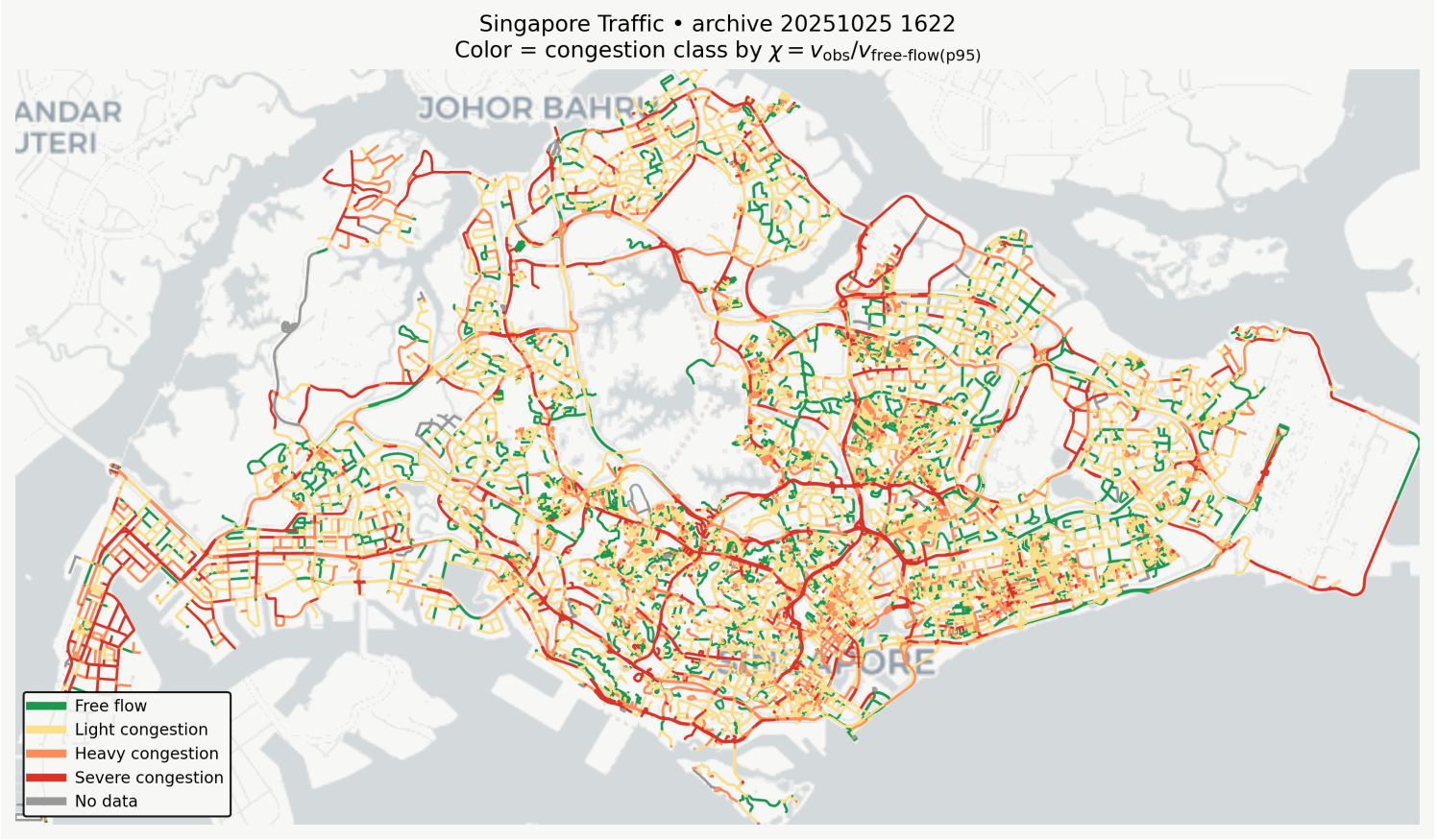
NaSch Model



Actual Data


Singapore Traffic • archive 20251025 1622
Color = congestion class by $\chi = v_{obs}/v_{free\text{-}flow(p95)}$
ANDAR
JTERI
JOHOR BAHRU
Free flow
Light congestion
Heavy congestion
Severe congestion
No data

Actual Data



$$\chi = \frac{v_{\text{obs}}}{v_{\text{free}}}$$

Class	Condition on χ
Free flow	$\chi \geq 0.90$
Light congestion	$0.70 \leq \chi < 0.90$
Heavy congestion	$0.50 \leq \chi < 0.70$
Severe congestion	$\chi < 0.50$
No data	χ undefined (NaN)

Methodology

Simulation Framework

$$V_{\text{opt}}(h_i, x_i) = \underbrace{B(x_i, \epsilon)}_{\text{Bottleneck Factor}} \cdot \underbrace{V_{\text{base}}(h_i)}_{\text{Base Optimal Velocity}}$$

$$B(x_i, \epsilon) = 1 - \epsilon \cdot \exp\left(-\left(x_i - \frac{L}{2}\right)^2\right)$$

$$V_{\text{base}}(h_i) = \frac{\tau}{L} \cdot \left(\frac{\tanh(h_i - 2) + \tanh(2)}{1 + \tanh(2)}\right)$$

OVM/IDM Numerical integration: $\Delta T = 0.005s$, simulation time: 8s

Highway	**N** (num. of vehicles)	$\boldsymbol{\tau}$ (reaction time)	$\boldsymbol{\alpha}$ (sensitivity)	$\boldsymbol{\epsilon}$ (perturbation factor)	$\boldsymbol{\chi_{base}}$ (target speed ratio)
Motorway	20	40	0.9	0.2	0.75
Trunk	15	35	0.85	0.3	0.80
Primary	12	30	0.8	0.4	0.85
Secondary	10	25	0.75	0.5	0.90
Tertiary	8	20	0.7	0.6	0.95
Residential	6	15	0.6	0.7	0.95

Cellular Automata

$\Delta T = 1s$

$\mathrm{N_{cells}} = 100$

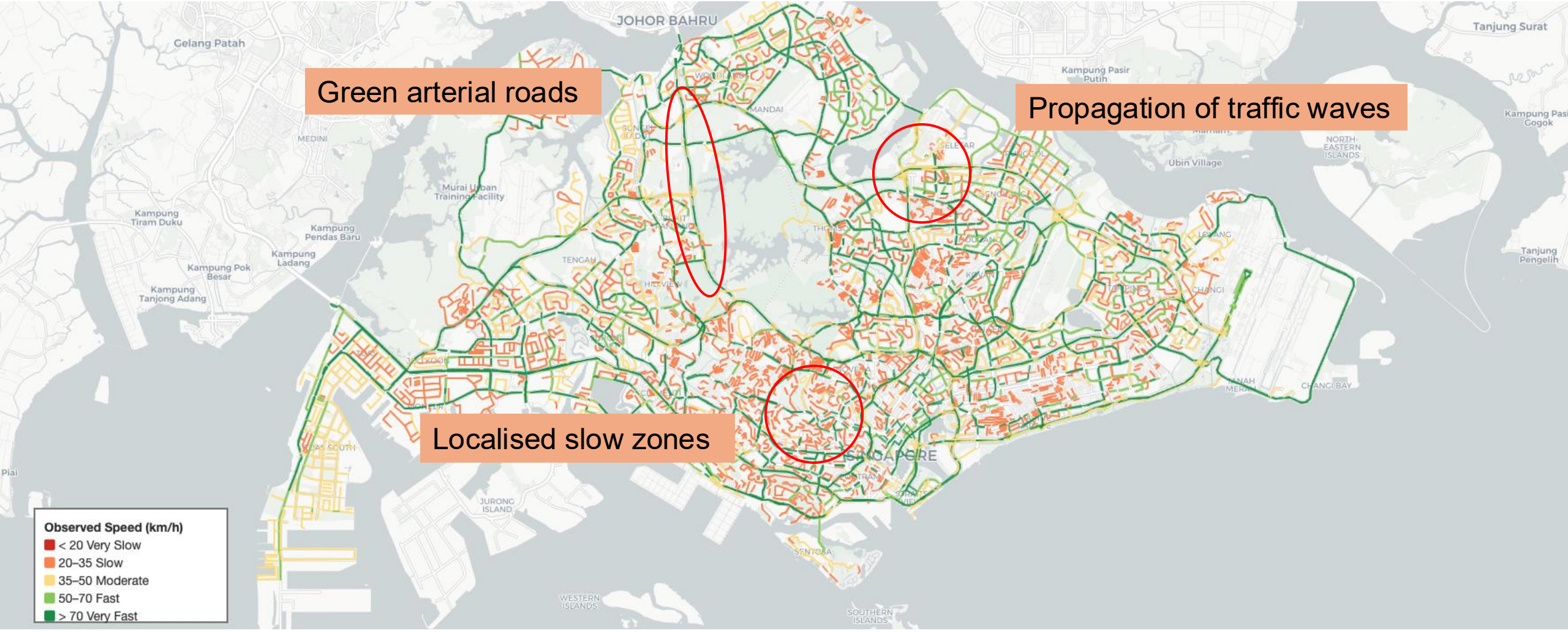
$\mathrm{L_{cell}} = 7.5m$

$\mathrm{v_{max}} = 5\text{cells/stp}$

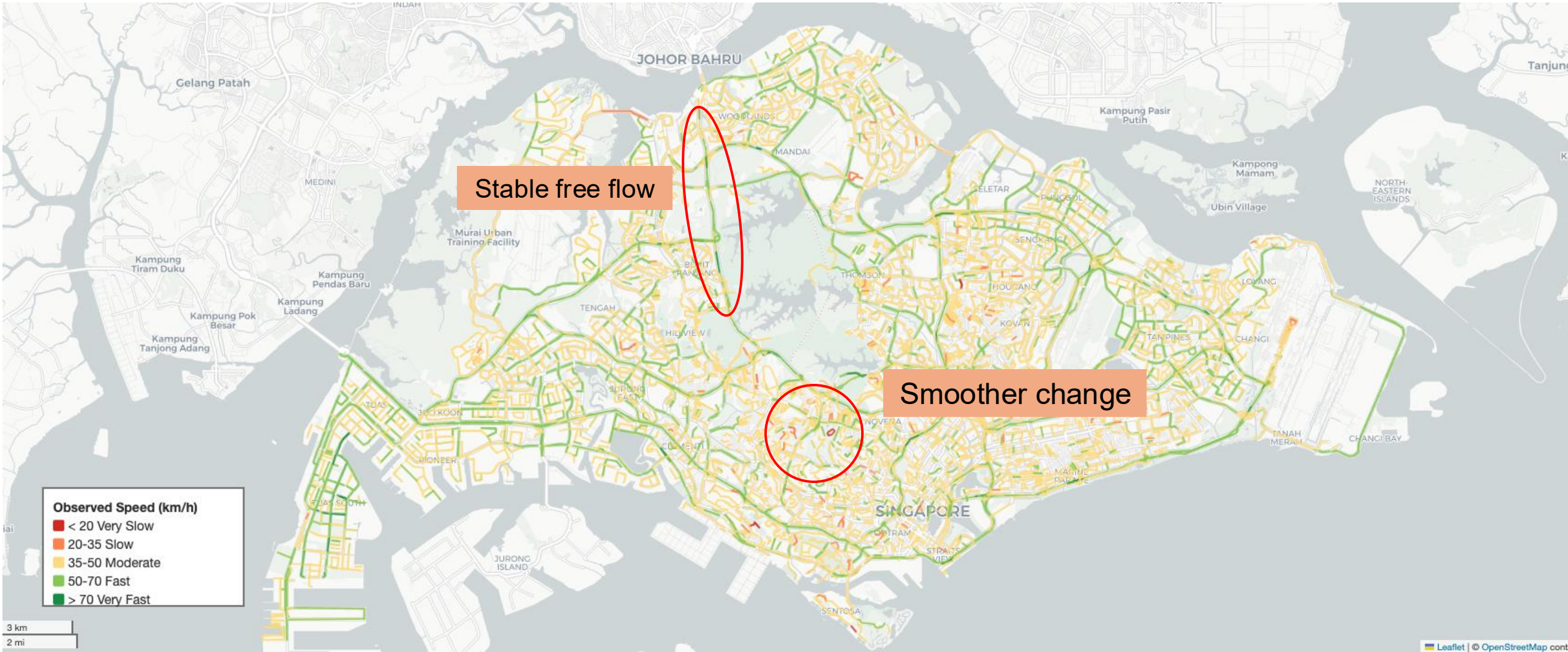
$\mathrm{N}_{cars} = 20$

Steps = 500

Simulation Results (NaSch)



Simulation Results (OVM)



Simulation Results (IDM)

Limitations

- Car-following only, no lane changing
- Time-sensitivity (peak hours)
- Traffic light systems
- Models are simplified
- Interactive traffic technologies
- Driver mistakes (irrational agents)